Measurement of the CMS HF radiation degradation using radioactive source (mathematical simulation)

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CERN, March 2002

Monte-Carlo generated processes in the HF:

radioactive source signal:

$\gamma(Co^{60}) \Rightarrow e^{-}(Compton) \Rightarrow \gamma(Cherenkov) \Rightarrow e^{-}(PMT)$

activation background signal:

$\gamma(ind.activ.) \Rightarrow e^{-}(Com.) \Rightarrow$

$\beta(ind.activ.) \Rightarrow \quad e^{-},e^{+} \quad \Rightarrow \quad \gamma(Cher.) \Rightarrow e^{-}(PMT\ bg)$

Main steps of the Monte Carlo program:

- generation of the space distribution of the fluxes of Compton and β electrons;
- electron transport to the surface of the optical fiber core (taking into account energy losses and multiple scattering);
- Cherenkov photon production;
- photon transport in the fiber and photoelectron production

Supposed parameters for source and background signal simulation without fiber degradation

- 13 towers of the HF sector segmentation with the source in the center of every tower;

- optical fiber grid has 5 mm spacing;

- optical fibers have 0.6 mm dia quartz core (refractive index 1.47) with 0.1 mm coating and a clad between them ($\Theta=38^{o}$);

- PMT quantum efficiency is taken according to the CMSIM version, PMT gain $g=4\cdot10^{4}$ electrons;

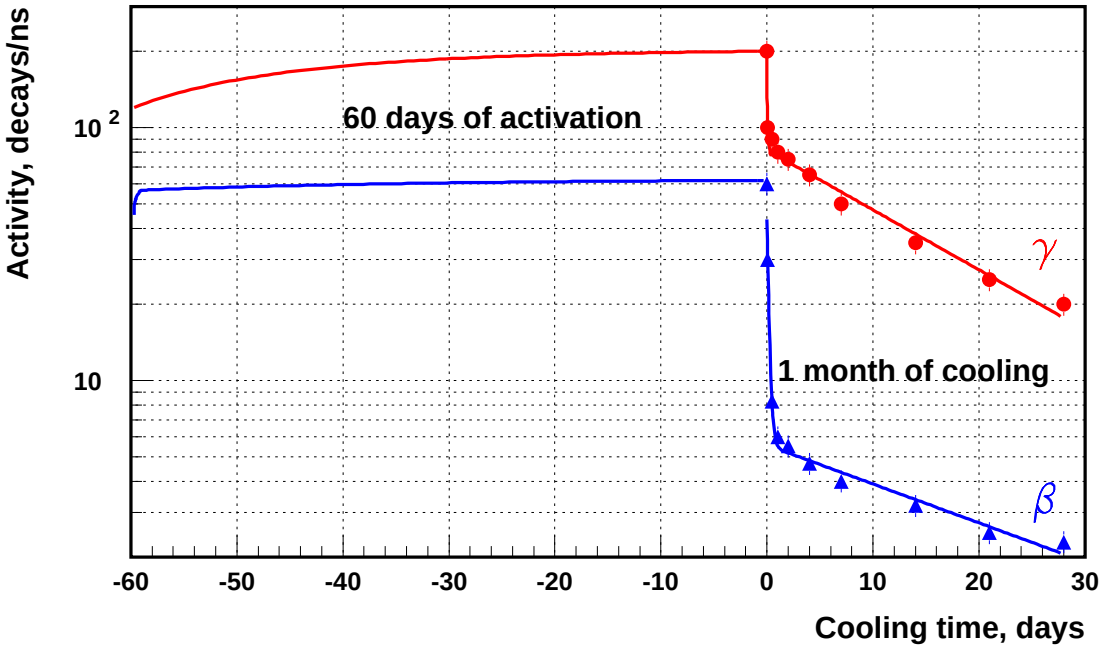
- some calculations were performed with additional cut on $\lambda>390$ nm of Chrenkov photon;

- cobalt radioactive source with 20 mCi activity is considered;

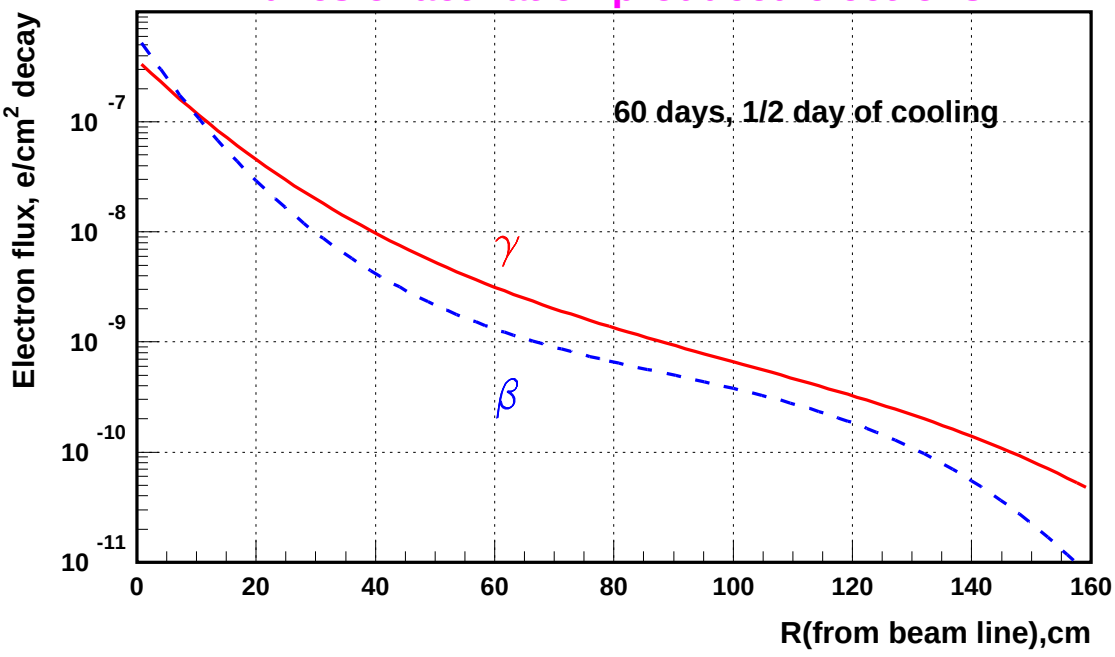
- activation background is taken for 0, 0.5, 7 and 28 days of cooling after 2 months of operation at high luminosity.

Induced activity of CMS HF absorber

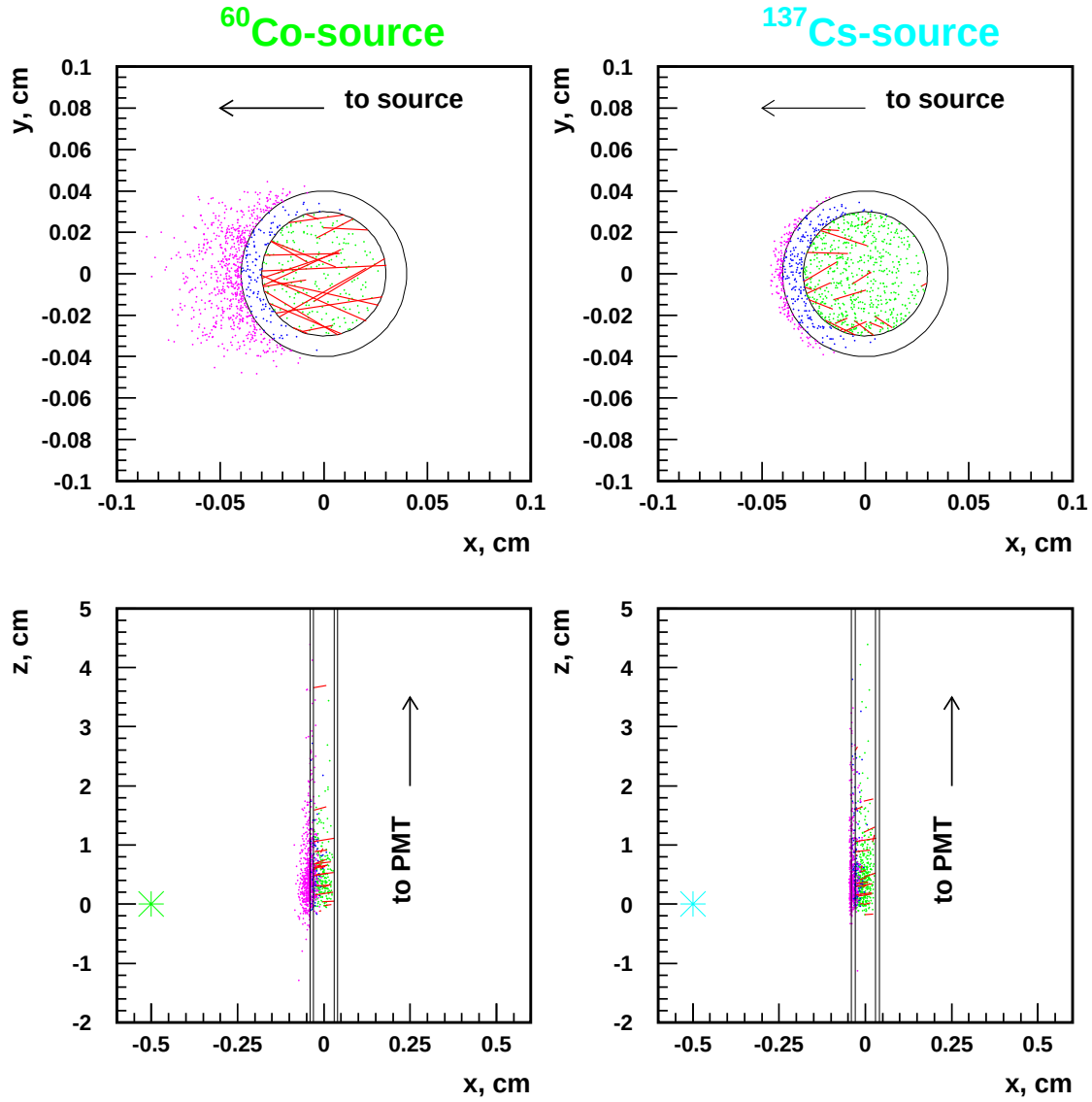
Dynamic of absorber activation



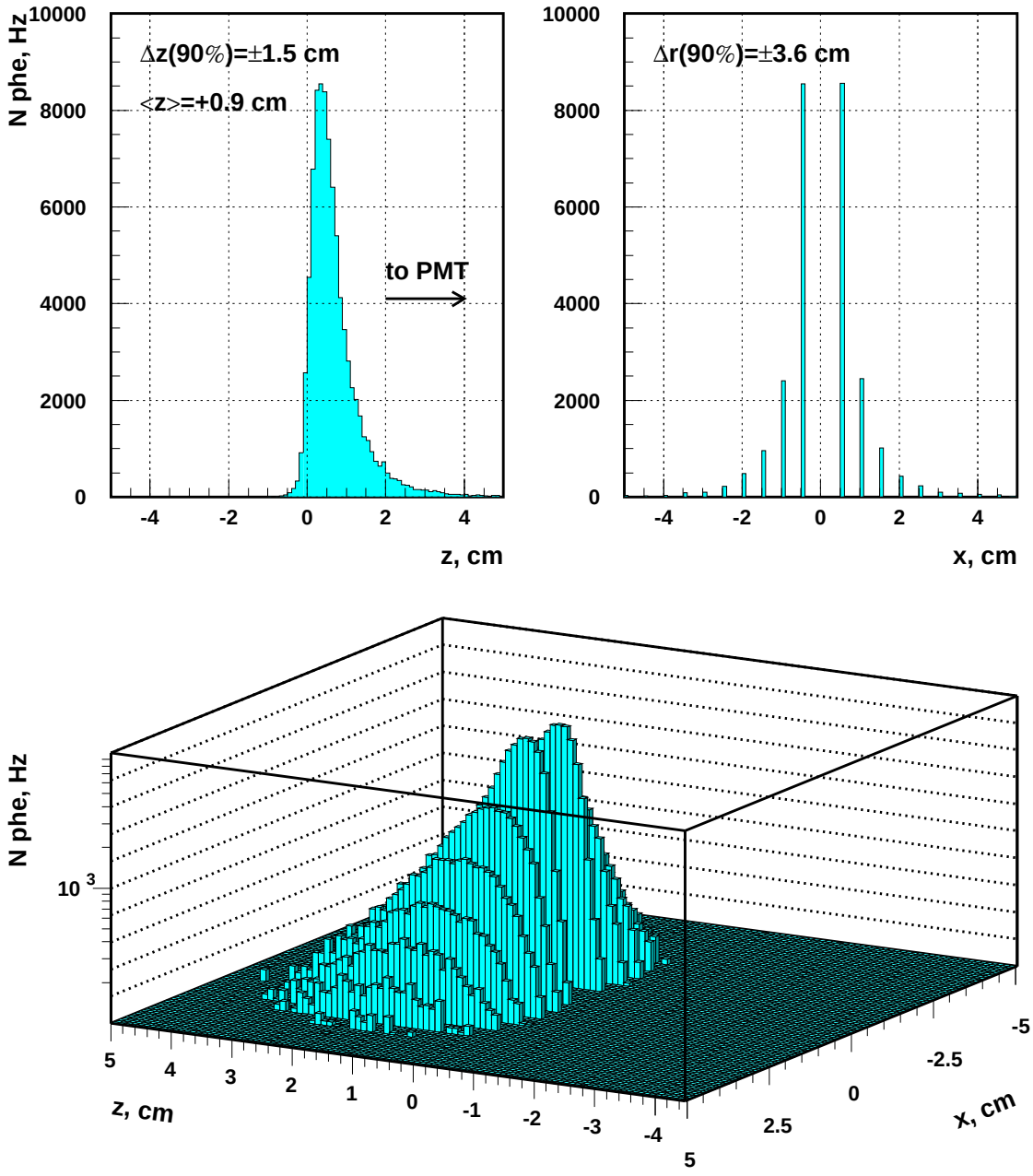
Fluxes of activation produced electrons



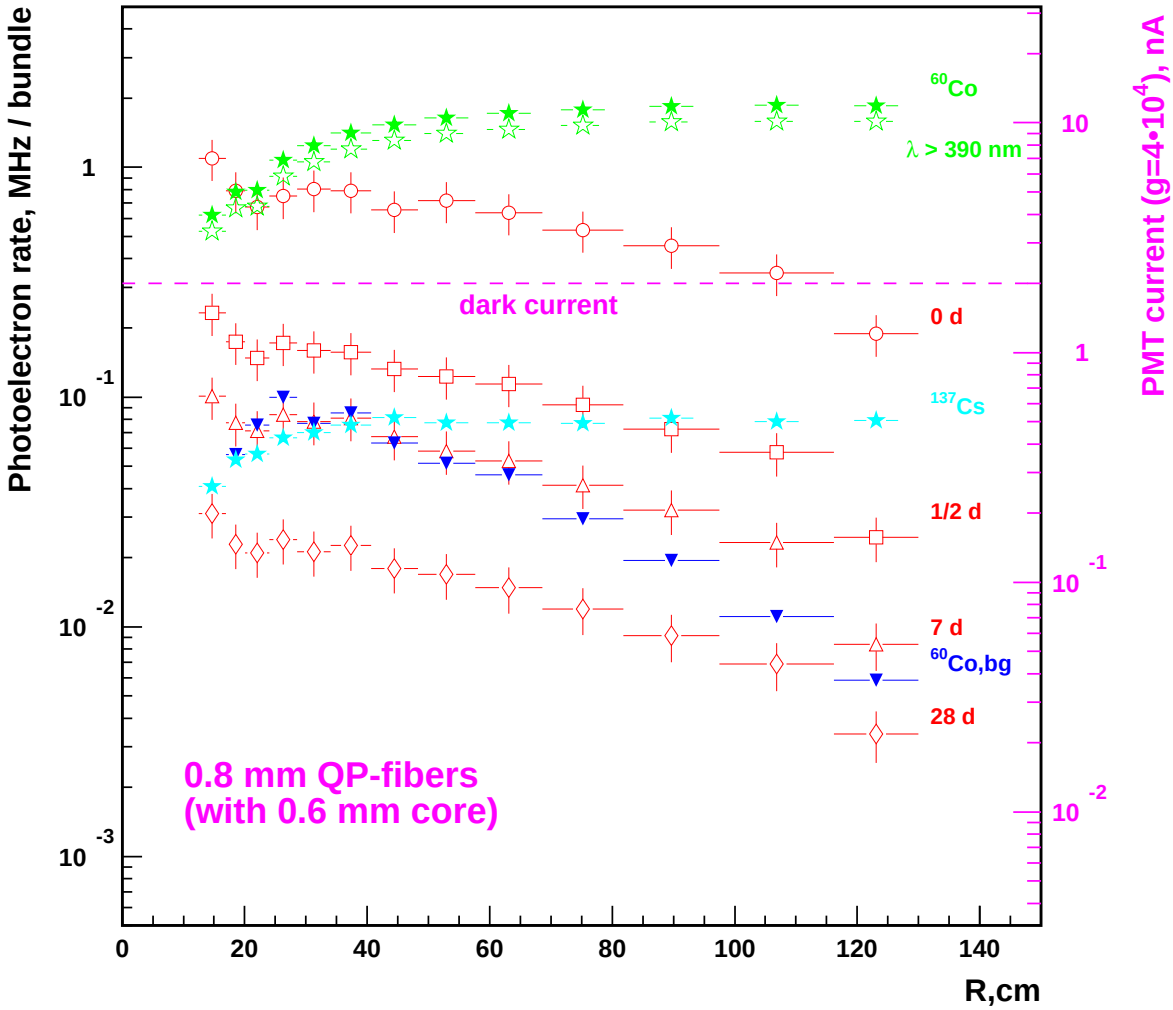
Space distribution of the Compton electrons in the fiber area (for non-zero signal)



Space sensitivity to radioactive source



Photoelectron rates and PMT currents



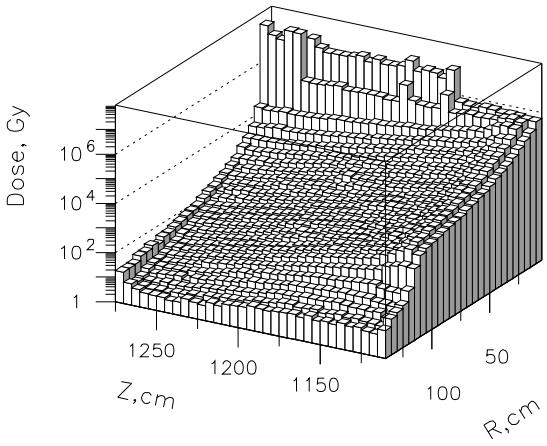
green closed stars - 20mCi ^{60}Co source in the center of bundle

blue closed stars - 20mCi ^{137}Cs source in the center of bundle

red open symbols - activation background for 0, 0.5, 7 and 28 days of cooling

blue closed symbols - neighbouring tower source background

Simulation of the source signal attenuation:



HF absorber 10-year total dose (calculated by M.Huhtinen)

Interpolation of Snezhinsk experimental data for light absorbtion in the quartz-plastic fibers after γ-irradiation:

$$A(\lambda) = a(\lambda) \cdot D^{b(\lambda)}$$

D - absorbed dose, Mrad

λ - wavelenth, nm

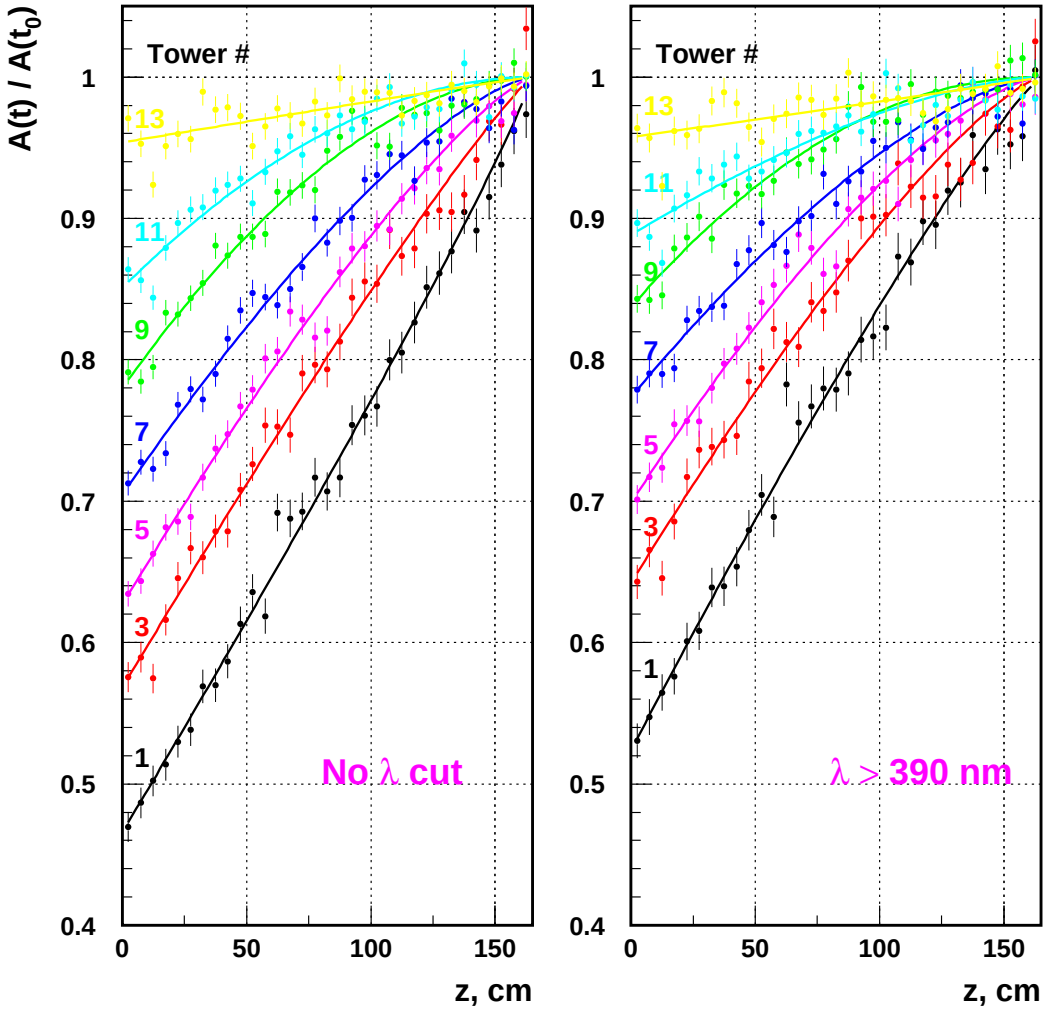
Attenuation A(λ), dB/m (calculated by A.Gribushin)

The probability for the every single Cherenkov photon (generated at z,r) to survive at the penetration of fiber is calculated as:

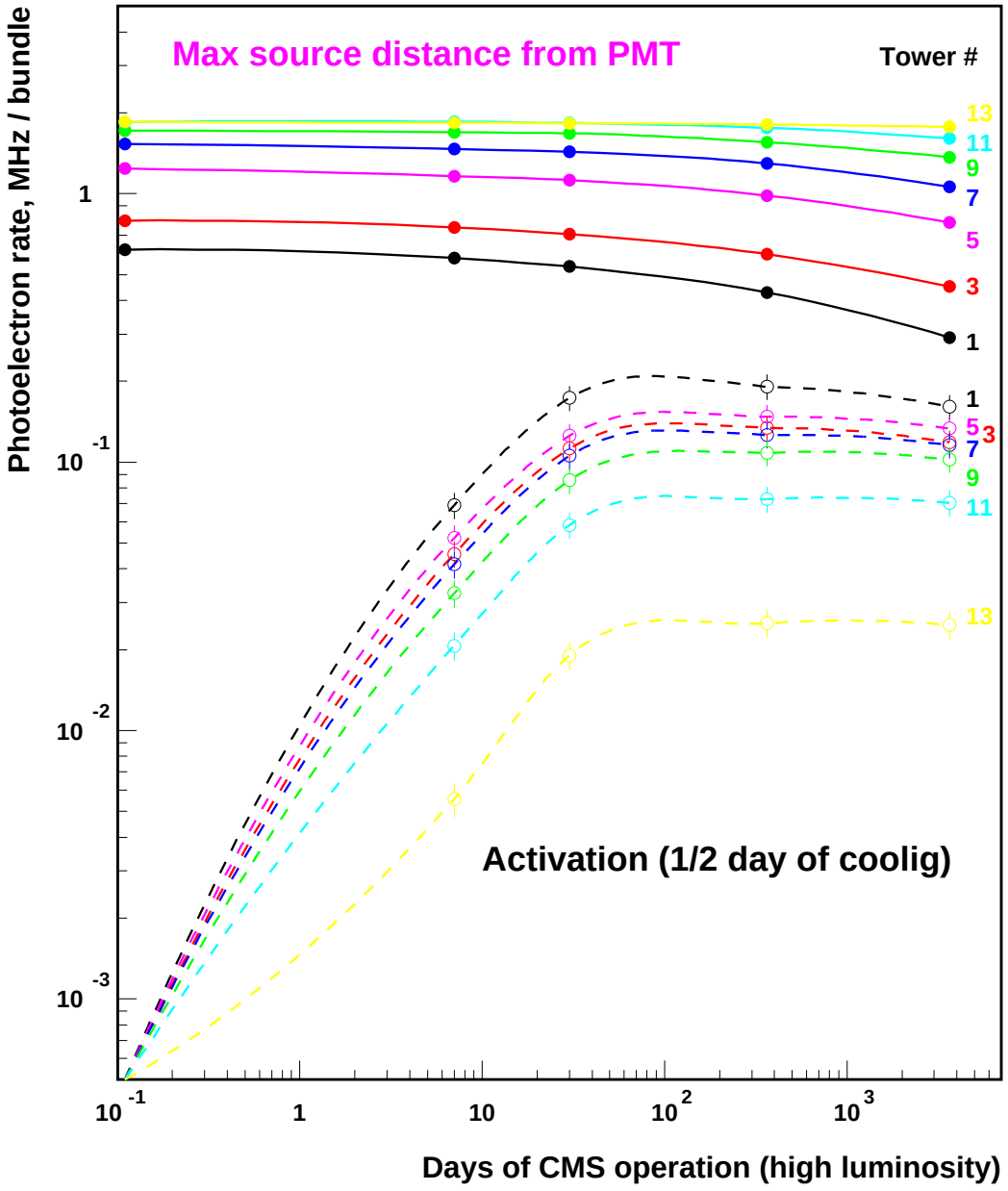
$$\exp(-\ln 10/10 \cdot \sum_{z} a(\lambda) D(r,z)^{b(\lambda)} \Delta z)$$

To calculate the HF responce to the source for any time of operation the total dose has to be reduced correspondingly

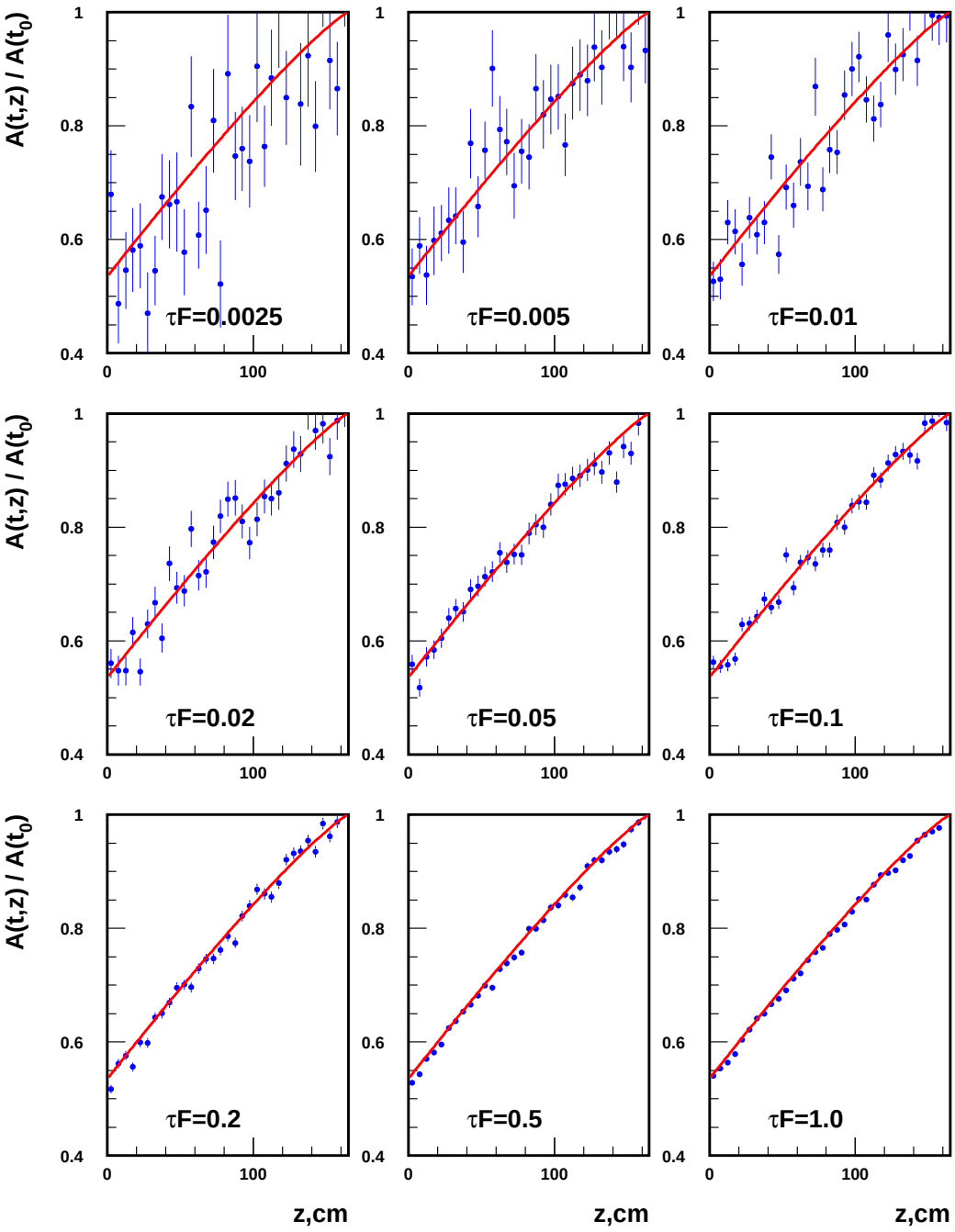
Source signal reduction after 10 years of irradiation



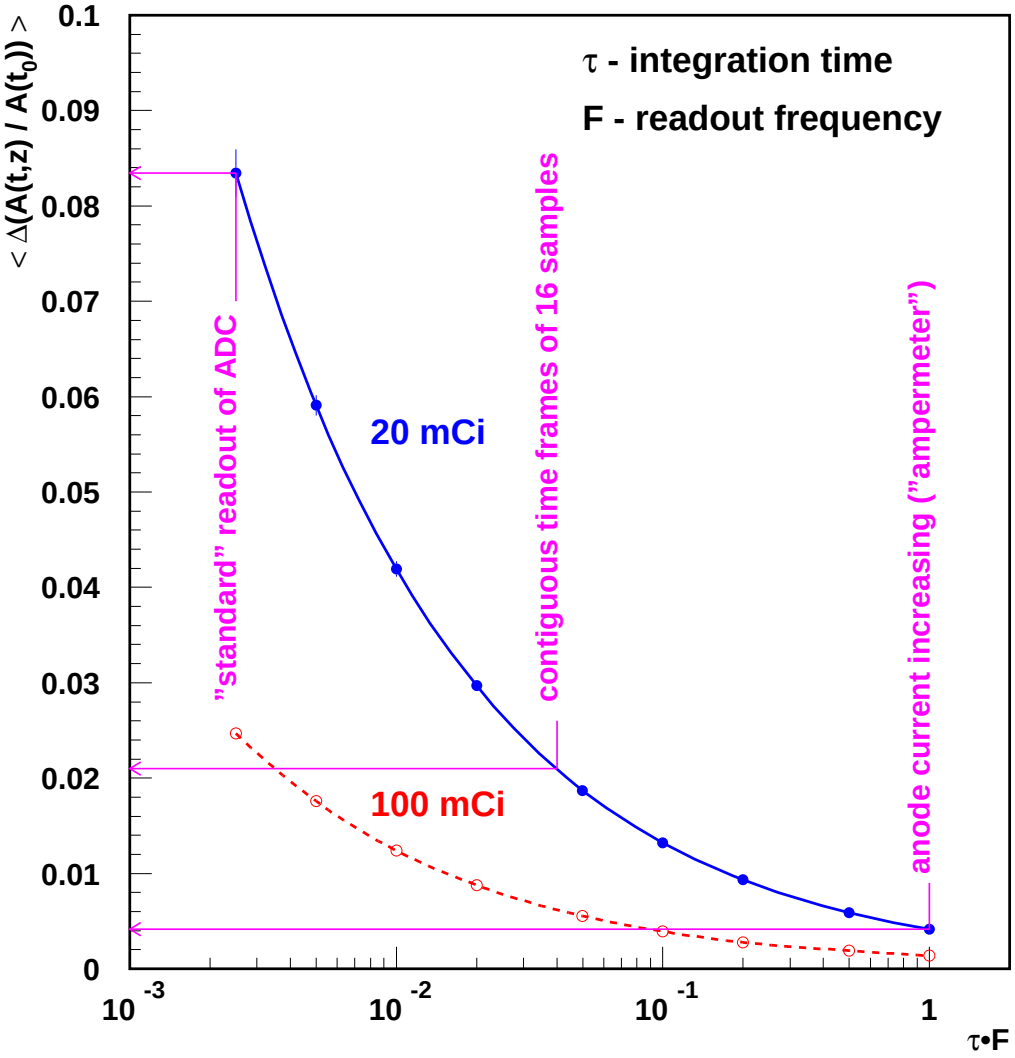
Dynamic of the source and background signals



Measurement of the fiber transparency (1st tower, 10 years of irradiation)



Precision of the fiber transparency measurement



To be done in 2002:

The procedure of the HF re-calibration using radioactive source has to be investigated by the mathematical simulation method.

It means that we need to fix the correspondence beetween the results of the source signal decreasing measurement $A(t,z) / A(t_0)$ and the corrections of the calibration coeffitients.

Firstly it can be done by the simulation of the energy reconstruction for Minimum Bias events under the corrections based on the source measurement.

One can hope that important experience for radioactive source measurements will come from the Summer 2002 Test Run